

BIOMEDICAL APPLICATIONS OF AEROSPACE
GENERATED TECHNOLOGY

QUARTERLY REPORT NO. 1
1 June - 31 August 1968

Contract No. NSR 26-002-083

MRI Project No. 3217-E(A)

For

National Aeronautics and Space Administration
Office of Technology Utilization
Technology Utilization Division
Washington, D. C. 20546

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by

David Bendersky

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PREFACE

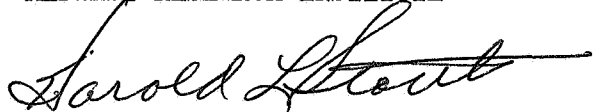
This report covers the activities of Midwest Research Institute's Biomedical Applications Team during the period from 1 June to 31 August 1968. The MRI BA Team is concerned with the application of aerospace-generated technology to problems in the nonaerospace biomedical field. This work is under the technical direction of NASA's Office of Technology Utilization, Technology Utilization Division, Washington, D.C.

The MRI BA Team is directed by David Bendersky, Principal Engineer, under the supervision of Paul C. Constant, Jr., Assistant Director of the Engineering Division. Other MRI technical staff who contributed to the activities reported herein are Edward T. Fago, Wilbur E. Goll and James K. West. The coordinators at the participating medical institutions are Dr. John W. Trank, University of Kansas Medical Center; Drs. Rick Heber, Robert H. Schwartz and Harry Ludwig, University of Wisconsin; Mathew L. Petrovick, Northwestern University; and Blair A. Rowley, University of Missouri.

The all-important contributions of the biomedical investigators at the participating medical institutions, whose names are given in the text, are gratefully acknowledged.

Approved for:

MIDWEST RESEARCH INSTITUTE



Harold L. Stout, Director
Engineering Division

6 October 1968

TABLE OF CONTENTS

	<u>Page No.</u>
Summary	1
I. Introduction.	2
II. Activities on Biomedical Problems	2
A. University of Missouri Problems	2
B. University of Kansas Medical Center Problems.	6
C. University of Wisconsin Problems.	8
III. Other Project Activities	11
A. Project Trips	11
B. Miscellaneous Activities.	12
IV. Plans for Next Quarter.	13
References	14
Appendix I - NASA Tech Briefs.	18
Appendix II - Papers presented at the Annual Meeting of the As- sociation for the Advancement of Medical Instru- mentation, Houston, Texas, 17 July 1968	23

SUMMARY

During June, July and August 1968, the Biomedical Applications Team at Midwest Research Institute was active on 19 problems submitted by the participating biomedical institutions, three of which were new problems. As a result of the BA Team activities, potential solutions were found to 12 of these problems. Five of these potential solutions have resulted in successful transfers of technology; namely, (1) a technique for enhancing X-ray photographs, (2) a temperature telemetry system for internal organs, (3) an enzyme electrode amplifier and telemetry system, (4) cardiac output measurement, and (5) a learning machine for mentally retarded children.

Project trips were made by BA Team members to (1) attend the NASA Technology Utilization Conference, Hampton, Virginia, (2) visit the University of Wisconsin and the University of Missouri to discuss biomedical problems, (3) attend the Annual Meeting of Association for the Advancement of Medical Instrumentation, Houston, Texas, where two papers were presented in connection with the session on the Application of Aerospace Technology to Biomedical Problems.

Other miscellaneous activities of the BA Team are reported.

I. INTRODUCTION

The MRI Biomedical Applications Team was established in 1965, under the sponsorship of the NASA Office of Technology Utilization, to assist in the transfer of aerospace-generated technology to the nonaerospace biomedical field. The MRI BA Team is a multi-disciplinary group consisting of personnel with training and experience in biology, computer technology, electrical engineering, medicine, mechanical engineering, pharmacology and physiology.

The procedure being used to transfer aerospace-generated technology to biomedical applications consists of five basic steps. The first step is to define specific biomedical problems. The problems are obtained from the research staffs at participating biomedical institutions. The second step is to identify potential solutions to the biomedical problems. The identification of potential solutions is done through computerized and manual literature searches, circulation of problem abstracts to the NASA Research Centers and aerospace contractors, and personal contacts. The third step is to modify the original technology, when required, to adapt it to the biomedical problem. The fourth step is the evaluation of the technology by the biomedical researcher who submitted the problem. The final step is to document and disseminate information on successful transfers.

Four biomedical institutions are presently participating in the MRI BA Team program. These are the University of Kansas Medical Center, Kansas City, Kansas; the University of Wisconsin, Madison, Wisconsin; Northwestern University Medical School, Chicago and Evanston, Illinois; and the University of Missouri, Columbia, Missouri.

II. ACTIVITIES ON BIOMEDICAL PROBLEMS

A. University of Missouri Problems

X-Ray Photograph Enhancement, Problem No. MU-8, Biomedical Investigator:
Dr. P. L. Reichertz

Dr. Reichertz is engaged in a program to eliminate noise, correct distortion and enhance contrast in X-ray photographs. The ultimate goal of the program is to provide enhanced X-ray photographs and computerized processing of X-rays to attain a diagnosis.

As a result of information on the X-ray enhancement technique developed at the Jet Propulsion Laboratory (JPL),^{1/}* previously furnished to Dr. Reichertz by the MRI BA Team, and a visit to the Jet Propulsion Laboratory, Dr. Reichertz is now in the process of setting up a similar system at the University of Missouri. A brief description of the JPL X-ray enhancement technique is given in NASA Tech Brief 67-1005, Appendix I.

Four additional documents^{2-5/} related to this problem were obtained by the MRI BA Team through a search of the NASA literature bank and sent to Dr. Reichertz during this report period for evaluation. The ability to use black and white photographic information, such as X-rays is limited by the observer's ability to distinguish shades of gray. Reference 2 describes a process, developed at the Rand Corporation, which enhances visual discrimination by keying measured light intensity in a photograph to color. Test data obtained from Mariner IV were processed and are shown in the reference. Reference 3 describes a program to find a better way to interpret photographic information below the threshold of human vision, conducted by the Houston Fearless Corporation. The program consisted of a study of enhancement techniques in general, a design study of instrumentation techniques required to achieve the most promising enhancement, and the fabrication of laboratory apparatus to demonstrate the techniques. Photographic, optical and electronic processing for image enhancement are discussed in Reference 4. The basic principles of enhancement filtering and matched filtering are described and the techniques used in both methods are reviewed in Reference 5.

Electrocardiogram Electrodes, Problem No. MU-9, Biomedical Investigator:
Dr. P. L. Reichertz

Small electrodes are needed for electrocardiograms which are satisfactory over comparatively long periods, are not affected by movements of the patient, and must not cause bedsores even when attached to the back of a motionless lying patient. These electrodes are needed for hospital coronary care units and are to be connected to a central computer network.

A NASA publication^{6/} describes the electrode system developed and used in the Mercury and Gemini projects. Conventional electrocardiogram techniques, although suitable for short-term use, were inadequate for long-duration space flights. Since the electrode was the weakest link, effort was devoted to maximize verifact and minimize artifact in these electrodes. The problem could not be solved by investigating the electrode alone. The electrode, the contact medium and the skin were considered as a system.

* References listed on pages 14-17.

The developed system included a small electrode (2 cm^2) consisting of a silver/silver chloride/gelatine matrix imbedded in a methylmethacrylate housing, a specially prepared electrode paste and decornification of the skin. Tests have shown that this electrode system is remarkably free of artifacts and provides a high quality signal for long periods.

A copy of Reference 6 was sent to Dr. Reichertz for evaluation in connection with Problem No. MU-9.

Tracking of Large Animals, Problem No. MU-11, Biomedical Investigator:

V. W. Zager

A method is needed for tracking and locating large animals by radio transmission signals. The transmission distance should be up to 5 miles and the power source life should ideally be several years.

A small telemetry unit, developed at the NASA Ames Research Center, may be applicable, with modifications, to the tracking of large animals. A brief description of the telemetry unit is given in NASA Tech Brief 64-10171,^{7/} Appendix I. Blair Rowley, the MRI BA Team contact at the University of Missouri, requested and received detailed technical information on this unit from the Ames Research Center for evaluation.

Cardiac Output Measurement, Problem No. MU-12, Biomedical Investigator:

Dr. P. L. Reichertz

A method is needed to evaluate the amount of blood being pumped by the heart through peripheral measurements. This type of measurement is particularly required for critically ill patients.

A manual search of the literature by the MRI BA Team revealed work done at the Cedars-Sinai Medical Research Institute, Los Angeles, California, supported by NASA, on the measurement of cardiac output by the vibrocardiogram.^{8/} An examination had been made of the relationship between heart stroke volume measured by the standard dye dilution technique and left ventricular contraction and ejection time as measured by the vibrocardiogram (taken with a capacitance microphone placed on the chest). Data were taken on 21 subjects. Analysis of the data showed that ejection time was highly correlated with stroke volume ($r = 0.84$), and the use of both ejection time and contraction time improved correlation to $r = 0.90$. It was concluded that the vibrocardiogram provides a simple, nontraumatic method for the estimation of the stroke volume.

A copy of Reference 8 was sent to Dr. Reichertz for evaluation. Dr. Reichertz reported that this NASA-supported technology "seems to be a valuable method for cardiac monitoring, especially when analogue computation equipment is available for continuous readouts. Apparently there is sufficient correlation to justify clinical experimentation. If results can be confirmed, this will be a valuable method to estimate stroke volume, perhaps superior to other nontraumatic methods, especially in regard to simplicity of operation."

Blood Pressure Measurement, Problem No. MU-18, Biomedical Investigator:
Dr. J. M. Martt

Dr. Martt is interested in obtaining a system for recording blood pressure during exercise tolerance tests. Because of motion and noise, present techniques for recording blood pressure in subjects undergoing exercise tests are awkward and inaccurate.

As a result of a computer search of the NASA literature tapes, nine relevant documents⁹⁻¹⁷ were obtained by the MRI BA Team and sent to Dr. Martt. One of these documents⁹ describes work done at Stanford Research Institute, under a NASA contract, on a blood pressure transducer for the temporal artery. One design of this device incorporated a differential transformer sensing element with a special mounting to reduce response to acceleration. Another transducer using strain-gauge techniques was extensively tested on experimental animals and compared with direct intra-arterial measurements, in which accuracies in the order of ± 3 to 5 percent were obtained.

Simultaneous Electrocardiograph Measurements, Problem No. MU-19, Biomedical Investigator: D. W. Douglas

This is a new problem submitted during this report period.

The conventional procedure for obtaining electrocardiograms from electrodes attached to the limbs is to respectively switch to each of the six sets of electrodes (multiplexing), so that the electrocardiogram from each is not a continuous record. For multiphase testing, wherein a number of physiological functions are monitored at the same time, it is desirable to measure all six electrocardiogram limb leads simultaneously. Experimental work on the simultaneous measurement of electrocardiograms from the six limb leads is now in progress at the University of Missouri in connection with the Missouri Regional Medical Program. There is some concern as to whether electrocardiograms collected simultaneously are comparable with electrocardiograms collected by multiplexing. David W. Douglas, Research Associate,

has requested the MRI BA Team to determine whether simultaneous electrocardiograms have been previously collected and, if so, the results.

A computerized literature search on this problem has been initiated.

Bio-Telemetry, Problem No. MU-20, Biomedical Investigator: Blair A. Rowley

This is a new problem submitted during this report period.

In connection with the Missouri Regional Medical Program at the University of Missouri, there is a general interest in bio-telemetry equipment for a wide variety of potential applications. Blair A. Rowley, Research Associate, requested technical information on the subminiature bio-telemetry unit developed at the NASA Ames Research Center, Moffett Field, California, which is briefly described in NASA Tech Brief B64-10171, Appendix I. Information was requested that would enable the construction of the unit. The requested information was furnished directly to Mr. Rowley by the Technology Utilization Office at the Ames Research Center.

Torso Position Effects on ECG, Problem No. MU-21, Biomedical Investigator: Blair A. Rowley

This is a new problem submitted during this report period.

In the University of Missouri's Regional Medical Program it is planned to take electrocardiograms with the subject in a reclining chair. Blair A. Rowley, Research Associate, requested information on data collected in the space program on the effects of body positions on electrocardiograms.

A computer search of the NASA literature on this problem has been initiated.

B. University of Kansas Medical Center Problems

Electrocardiogram Electrodes, Problem No. KU-1, Biomedical Investigator: Dr. R. M. Lauer

In response to a request by Dr. Q. Hartwig, Project Monitor, a spray-on electrode²⁰ kit* was sent to Dr. R. T. Moxley, NASA Headquarters,

* Manufactured by Hauser Research and Engineering, Boulder, Colorado.

Washington, D. C. Dr. Moxley plans to use these electrodes to obtain electrocardiograms in a study of NASA executives.

Respirometer Helmet, Problem No. KU-5, Biomedical Investigator: Dr. R. M. Lauer

In response to a request by Dr. Q. Hartwig, Project Monitor, a respirometer helmet^{21/} was sent to Dr. R. T. Moxley, NASA Headquarters, Washington, D.C. Dr. Moxley is using this helmet to obtain oxygen consumption data in a study of NASA executives.

Requests for information on the respirometer helmet were received from and furnished to Sigma Educational Films, Studio City, California; Dr. William F. Miller, Methodist Hospital, Dallas, Texas; and Dr. James Brown, Research Triangle Institute, Durham, North Carolina.

Bone Density and Integrity, Problem No. KU-8, Biomedical Investigator: Dr. L. Peltier

There is a need for a nondestructive method for determining bone density and integrity without the necessity of normal X-ray procedures or surgery. A number of bone anomalies are associated with changes in bone density. Also, in many cases the diagnosis of some forms of hairline and nondisplaced fractures are not readily detected by normal X-ray visualization. Furthermore, the state of fracture healing may be related to bone density at the fracture site.

Instrumentation for bone density measurement has been developed by the Kanson Instruments Company, under contract to the NASA Manned Spacecraft Center.^{19/} The system is used to evaluate the integrated bone density over a specific cross-section of the bone. A roentgenogram of a standard aluminum calibration wedge and the bone specimen is obtained in a single exposure. Optical transmittance of the developed film is then measured by a scanning microdensitometer. The image of the aluminum wedge is first scanned to determine optical transmittance versus wedge thickness. The bone image is scanned next, resulting in a second output voltage curve. A computation system connects the voltage output for the bone to a curve of equivalent density, in terms of wedge thickness, and integrates the area under the density curve.

A copy of NASA Tech Brief 68-10140, Appendix I, which describes this bone density measurement system, was sent to Dr. Peltier for evaluation.

C. University of Wisconsin Problems

Measurement of Body Motion, Problem UW-4, Biomedical Investigator: Dr. M. E. Kaufman

One of the behaviors of severely mentally retarded children is body rocking while seated. This motion involves rhythmic swaying of the torso from front to back and from side to side. Apparatus for the measurement of this body motion is desired.

The MRI muscle accelerometer was considered to be a potential solution and two units had been furnished for evaluation.

Dr. Kaufman advised that the muscle accelerometer is not a satisfactory solution to this problem. It seems that the violent and unpredictable movements of the severely mentally retarded children being tested were sufficient to destroy the units. Prior to destruction, it was determined that the information obtained could not be readily interpreted. An observer could do a better job of correlating the subject's motions with other related stimuli and thus get an overall picture of total muscle activity.

The investigator now plans to video tape the subject's body motions from two different angles simultaneously and then reduce the video information to digital form suitable for computer analysis. This method should provide the psychologist with data suitable for determining gross body motion activity.

Apparatus for Learning Research, Problem UW-5, Biomedical Investigator: Dr. R. Heber

There is a need for a functionally flexible apparatus for experiments on visual learning, memory and other performance characteristics of mentally retarded children. This apparatus must be compact so that it can be readily moved from school to school.

A computer search of NASA literature was conducted. Although several related references were found in the search, no apparatus was found which would meet the requirements specified.

A proposal to develop the desired apparatus has been prepared by MRI and submitted to Dr. Heber. Dr. Heber has requested funds from the Social Rehabilitation Service to construct this apparatus.

Monitoring for Auditory Stimulation and Infant Vocalization, Problem UW-6,
Dr. R. Heber

There is a need for a tamperproof, miniaturized device for transmission of auditory stimulation impinging upon an infant and the infant's vocal response. The recording system should be capable of picking up the signal from a distance of one mile and should be capable of storing up to 12 hr. of data.

A computer search of the NASA literature had not revealed a solution to this problem.

A member of the BA Team has suggested to Dr. Heber that consideration be given to the use of low-frequency carrier current equipment which could operate over the commercial power lines and eliminate some of the problems which would otherwise be associated with the use of radio transmitting equipment. "Leased lines" from Western Union or the Telephone Company could also be used.

Temperature Telemetry for Internal Organs, Problem UW-10, Biomedical Investigator, Dr. R. K. Meyer

Dr. Meyer and his colleagues in the Zoology Department at the University of Wisconsin are doing endocrinology research on monkeys. In connection with this work, there is a need for an instrument which can be used to measure and telemeter the temperatures of internal organs and body cavities in the monkey. The instrument must be able to detect temperature changes as small as 0.02°F, and must remain operative inside the animal for several months without adverse reaction to the animal.

A computer search of NASA literature had revealed work done at the NASA Ames Research Center on a small temperature telemetry system briefly described in Tech Brief 66-10057, Appendix I. This equipment has been commercialized by the Electro-Optical Company, Pasadena, California. Information on this NASA temperature telemetry system was sent to Dr. Meyer for his consideration. Two units were procured by Dr. Meyer from the Electro-Optical Company. One unit has now been in use for over three months. The temperature telemetry unit is still functioning very satisfactorily in an ovariectomized monkey being used in the study of steroid compounds.

Rotary Joints for Small Cannulas, Problem UW-17, Biomedical Investigator:
B. D. Honeycutt

In tests on animals, small tubes are attached to the animal for introducing various liquids to the circulatory system. The animal is

permitted to move around while the liquids are introduced through the flexible tubing from an overhead container. Since the animal moves about and the container is stationary, twisting of the tubing occurs which obstructs the liquid flow. A rotary joint is required which will avoid twisting of the tubing. The investigator had been unable to locate an appropriate rotary joint for this application.

A computer search of NASA literature did not reveal any reports related to small rotary joints. However, literature on a commercial cannula feed-through swivel (Leheigh Valley Electronics, Fogelville, Pennsylvania) was obtained and sent to Mr. Honeycutt. Mr. Honeycutt reported that the Leheigh swivel was unsatisfactory.

Remote Manipulation of Brain Electrodes, Problem UW-18, Biomedical Investigator: Dr. C. N. Woolsey and Dr. J. F. Brugge

In the recording from single neurons in the brain of animals; there is a need for a reliable device to advance and withdraw a microelectrode over a distance of several millimeters. The drive unit must be small enough so that when it is on the head it does not interfere with the animal's behavior.

A computer search of the NASA literature had revealed a Russian report^{23/} which described a method for the automatic manipulation of brain electrodes. Followup information indicated that the Russian system did not lend itself to miniaturization and therefore would not be usable for free-roaming animals.

A manual search of the technical literature revealed an article on work done at the Johns Hopkins Medical Center on a depth gauge for micro-electrodes^{24/} which appears to be a possible solution. Another article describes a probe to monitor electroanesthesia current density,^{25/} conducted at the Polytechnic Institute of Brooklyn. Copies of these two references were forwarded to Dr. Brugge for evaluation.

Enzyme Electrode Amplifier and Telemetry System, Problem UW-20, Biomedical Investigator: Dr. S. J. Updike

Dr. Updike has developed a special enzyme electrode which he intends to use for the continuous monitoring of oxygen and glucose concentrations in living animal tissues. He needs a very stable, high-impedance amplifier in order that changes in the amplifier will not mask the signal he is attempting to measure.

Following a review of the computer search of NASA literature, Dr. Updike requested four documents²⁶⁻²⁹ for his further evaluation, which were obtained and sent to him. Three additional articles³⁰⁻³² which appeared to offer possible solutions were also sent. The latter were identified by the MRI BA Team through routine scanning of NASA and the open literature.

Dr. Updike has reported that the information given in References 27, 28 and 29 is helpful and that a pilot clinical project has been initiated.

Foot-to-Floor Force Measurements, Problem UW-21, Biomedical Investigator:
Robert J. James

This problem involves the measurement of forces exerted by the human foot against the walking surface in order to analyze the gait of mentally retarded children.

A computer search of the NASA literature did not reveal any useful information. However, a manual search turned up a NASA document³³ containing technology directly applicable to problem requirements. Additional scanning of the technical literature produced four additional articles⁵⁴⁻³⁷ containing possible solutions or relevant information. Also supplied was commercial literature³⁸ on the load cells used to construct the force stand described in References 34 and 35.

All of the above information has been forwarded to the investigator for further evaluation.

III. OTHER PROJECT ACTIVITIES

A. Project Trips

June 4-6, 1968--Paul Constant, Jr., attended the NASA Conference on Technology Utilization, held at Langley Research Center, Hampton, Virginia. The activities of the Biomedical Applications Teams were discussed during this conference.

June 25-26, 1968--Wilbur E. Goll visited the University of Wisconsin, Madison, Wisconsin, and discussed the status of the various biomedical problems submitted by the investigators at this school.

July 3, 1968--James K. West visited the University of Missouri, Columbia, Missouri. Discussions were held with investigators relative to the biomedical problems submitted from this school.

July 9 and 10, 1968--David Bendersky attended a meeting in Washington, D. C. Representatives of NASA, George Washington University and the three Biomedical Application Teams reviewed the papers to be given at the AAMI meeting in Houston, July 17, 1968.

July 17, 1968--David Bendersky attended the AAMI (Association for the Advancement of Medical Instrumentation) Meeting in Houston, Texas. Two papers concerning the MRI BA Team were presented by Mr. Bendersky at this meeting. Copies of these papers are given in Appendix II.

B. Miscellaneous Activities

1. The status of each problem submitted to the MRI Biomedical Team was prepared and sent to the contact men at each of the participating schools.

2. In response to a request from Lynn S. Wilson, George Washington University, Biological Sciences Communication Project, a special report on the temperature telemetry transfer, Problem No. UW-11, was prepared and sent to Mr. Wilson. Also, two extra copies of the Final Report on NASA Contract No. NASr-63(13)²⁰ were requested by and sent to Mr. Wilson.

3. A copy of a report on a flexible tether,²² which had been cited in a previous MRI BA Team report,²⁰ was requested by and sent to Mr. H. Emerson, Technology Utilization Office, NASA Ames Research Center, Moffett Field, California.

4. Mr. Robert Bell, NASA Technology Utilization Office, Washington, D. C., visited Midwest Research Institute, 31 July 1968 to discuss the BA Team program.

5. Mr. Donald Eulert, Sandia Corporation, Albuquerque, New Mexico, visited Midwest Research Institute on 22 July 1968 to discuss the BA Team program.

6. Information on the respirometer helmet (KU-5), cardiac output measurement (KU-14), and sterile operating rooms (UM-1) were requested by and sent to Dr. James N. Brown, Director of the BA Team at Research Triangle Institute, Durham, North Carolina.

7. Information on a coupling unit for ultrasonic energy which may be applicable to Problem No. WSM-1, was sent to Dr. Ray W. Ware, Director of the BA Team at Southwest Research Institute, San Antonio, Texas.

8. Information on the MRI muscle accelerometer was requested by and sent to Mr. Phillip Snyder, Engineering Manager, Medical Electronics, Radio Corporation of America, Trenton, New Jersey.

9. Captain M. Reich, Medical Officer, Fitzsimmons Hospital, Denver, Colorado, and Dr. Q. Hartwig contacted David Bendersky and requested that a visit be made to Fitzsimmons Hospital to determine how the MRI Biomedical Applications Team can assist them. Mr. Bendersky will contact Dr. Reich after the 3rd of September (Dr. Reich will be out of the country until then) to establish a visit date.

IV. PLANS FOR NEXT QUARTER

1. The search for aerospace-derived technology which may be applicable to the problems submitted by the participating medical schools will be continued.

2. Additional problems will be solicited from the participating medical schools. A mailing will be made to the staff at the University of Kansas Medical Center to stimulate the submission of additional problems.

3. Visits will be made to each of the participating schools to discuss problems already submitted and to solicit additional problems.

4. A visit will be made to the Fitzsimmons Hospital, Denver, Colorado, to determine how the MRI Biomedical Applications Team can serve this institution.

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APPENDIX I

NASA TECH BRIEFS

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68-10140

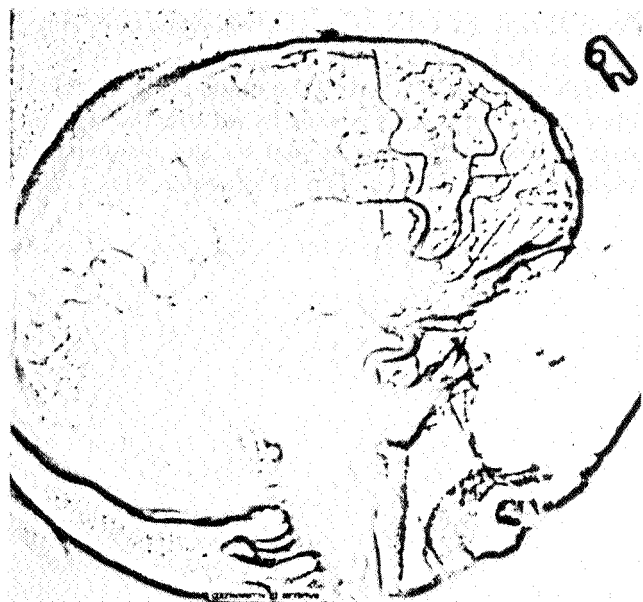
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NASA TECH BRIEF



NASA Tech Briefs are issued to summarize specific innovations derived from the U.S. space program, to encourage their commercial application. Copies are available to the public at 15 cents each from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

Digital Computer Processing of X-Ray Photos



The problem:

The interpretation of medical and biological pictures such as X-ray photographs could be made easier if selected portions of the image were first enhanced by means of a digital computer.

The solution:

For a number of years, digital computers have been used at Jet Propulsion Laboratory to correct various photometric, geometric, and frequency response distortions in the pictures received from the television cameras of the Ranger, Mariner, and Surveyor spacecraft. These methods have now been applied to the study of medical and biological photographs.

How it's done:

The first step in the process is to convert the picture into a form suitable for input to the computer. This is accomplished by means of a cathode-ray tube device that scans the film with a light beam on a line-by-line basis and converts each point of the picture to a number proportional to the film optical density. Each sample (typically 500,000 samples for a 1-in.-sq. transparency) is recorded on magnetic tape which is subsequently fed into a computer.

One of the principal methods of computer enhancement involves the use of a two-dimensional digital filter to modify the frequency spectrum of the picture.

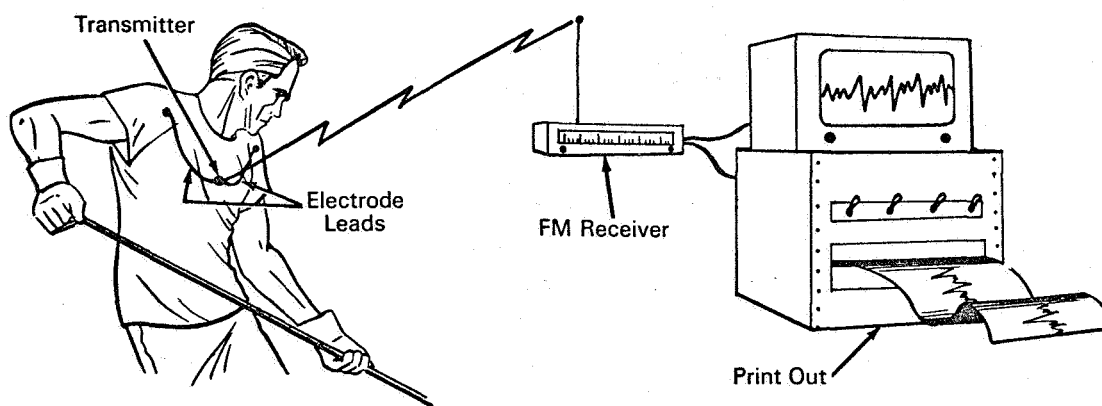
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NASA TECH BRIEF



This NASA Tech Brief is issued by the Technology Utilization Division to acquaint industry with the technical content of an innovation derived from the space program.

Subminiature Biotelemetry Unit Permits Remote Physiological Investigations



The problem: The measurement of biopotential response in humans or animals to controlled environmental stimuli has traditionally been impaired by encumbering electrical leads or bulky amplifying and transmitting equipment.

The solution: A subminiature, high-performance, biopotential telemetry transmitter operating in the standard 88- to 108-megacycle FM band.

How it's done: The transmitter was designed using standard, inexpensive, commercially available components and assembly techniques which permit easy and repeatable assembly with no sacrifice of performance or reliability. The transmitter is 0.74 inch in diameter by 0.20-inch thick and weighs two grams. A mercury cell provides power for operation in two modes, selected by the interchange of three components in the basic circuit. In one mode the transmitter has a two-day operating life with a 100-foot range; in the other, the transmitter has a 48-day operating life with a 10-foot range. Conventional biomedical electrodes are used to connect the transmitter to the subject.

Notes:

1. In tests, humans have worn the unit for four or five days without discomfort and have generated useful data while engaged in normal activities.
2. Further information concerning this innovation is described in NASA-TM-X-54068, "A Miniature Biopotential Telemetry System" by Gordon J. Deboo and Thomas B. Fryer, May 1964.
3. A related innovation is described in NASA Tech Brief 64-10025, May 1964.
4. Inquiries may also be directed to:

Technology Utilization Officer
Ames Research Center
Moffett Field, California, 94035
Reference: B64-10171

Patent status: NASA encourages commercial use of this innovation. No patent action is contemplated.

Source: Ames Research Center (ARC-39)

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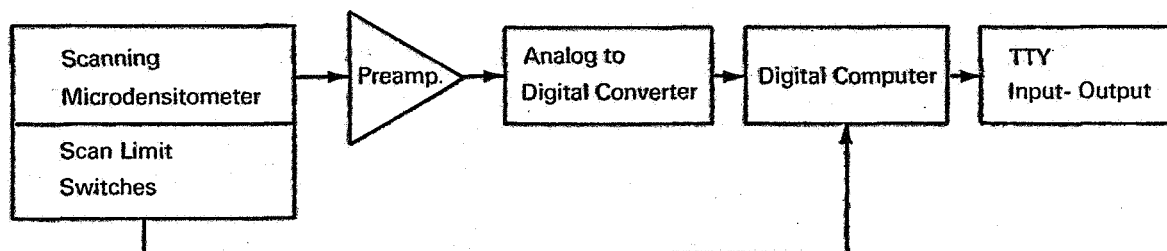
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Instrumentation for Bone Density Measurement



Bone density measurement systems with quite acceptable accuracy have been in use for some time. However, as increased interest in this area demands more and more data, the analog instrumentation used for data reduction lacks sufficient speed.

The basic measurement system evaluates the integrated bone density over a specific cross section of bone. A roentgenogram of a standard aluminum calibration wedge and the bone specimen is obtained in a single exposure. Optical transmittance of the developed film is then measured by means of a scanning microdensitometer. The image of the wedge is first scanned to determine optical transmittance versus wedge thickness as recorded on the film. Graphical representation of the optical scanner output for a scan of the wedge image is in the form of an output voltage curve. The bone image is scanned next along the desired cross section, resulting in a second output voltage curve. These curves are the basic inputs for measurement of bone density.

The computation system must now convert the voltage output for the bone scan to a curve of equivalent density (in terms of wedge thickness) and integrate the area under the resulting curve. Conversion between output for the bone scan and equivalent wedge thickness is made using the wedge scan curve. The curve is entered at the value of optical scanner

output and wedge thickness is read on the abscissa. This equivalent wedge thickness is used in the subsequent integration of the density.

In one analog system, in use for many years, conversion between optical scanner output during bone scan and equivalent wedge thickness, is made by using a nonlinear resistance slidewire output from a chart recorder. Integration is accomplished with an electro-mechanical integrator.

A system using a digital computer has been implemented to perform the computation functions similar to those performed by the analog system. Optical scanner output voltage is converted to a digital format for storage and subsequent processing by a digital computer. After both wedge and bone scans have been completed, the computer converts stored bone scan data to equivalent wedge thickness by using the stored wedge scan data. Bone density is then integrated along the scan by using the trapezoidal approximation integration formula. A block diagram of the digital instrumentation is shown in the figure.

In operation, data collection by the computer is controlled by the limit switches of the densitometer, which mark the beginning and end of the scans. Sampling times are controlled by a clock in the computer. The teletype unit is used to control the computer by directing it to prepare for a wedge or bone

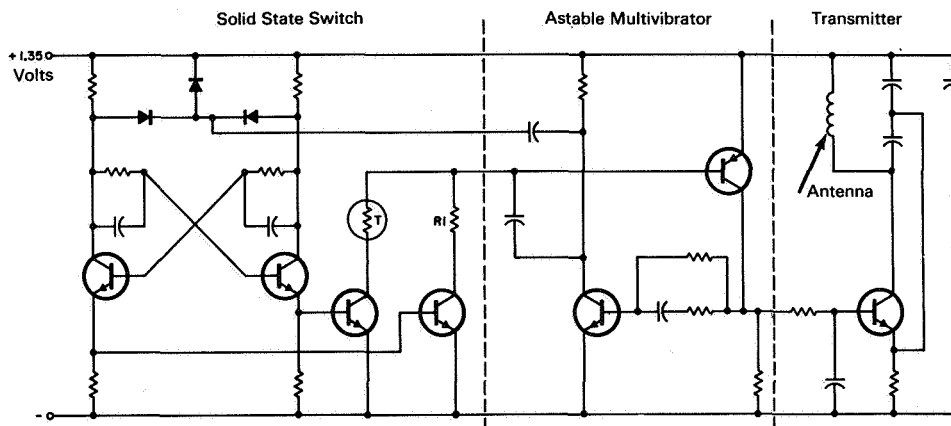
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NASA TECH BRIEF



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Miniature Bioelectronic Device Accurately Measures and Telemeters Temperature



The problem:

To design a microminiature implantable instrument that will continuously and accurately measure and telemeter the body temperature of laboratory animals over periods up to two years. The implanted instrument must be impervious to attack by body fluids and have a negligible effect on the physical activity of the animal.

The solution:

A miniature micropower solid-state circuit employing a thermistor as a temperature sensing element (with a compensating resistor) and a FM transmitter. The circuit is designed to be very stable for a long period and to be accurate to within 0.1°C . The instrument may be constructed from conventional discrete components or integrated circuits. A special feature of the instrument with integrated circuitry is that the

electronic components are sealed in a metal can, separate from the battery, so that seal rupture due to battery out-gassing is not a problem.

How it's done:

The circuit operates in the FM broadcast band and may be used with a commercial FM receiver. It transmits 15-microsecond pulses spaced 8 to 20 milliseconds apart, depending on the temperature being monitored (45° to 30°C). The average current drain of the circuit is approximately 7.4 microamperes at 1.35 volts.

A bistable multivibrator alternately switches the temperature sensor (a thermistor and a standard resistor, R1) into the frequency determining circuit of the astable multivibrator. The demodulator produces an output proportional to the ratio of the pulses obtained from the thermistor and the standard resistor.

(continued overleaf)

APPENDIX II

"Recent Successes Utilizing Aerospace Technology"

"Evaluating Aerospace Technology on the Medical Setting"

Papers presented at the Annual Meeting of the Association for the Advancement of Medical Instrumentation, Houston, Texas, 17 July 1968.

RECENT SUCCESSES UTILIZING AEROSPACE TECHNOLOGY

by

David Bendersky
Director, MRI Biomedical Applications Team

The Biomedical Applications Team at Midwest Research Institute is working with six midwest medical institutions to solve biomedical engineering problems through the application of aerospace technology. The medical institutions with who we are working are the University of Kansas Medical Center, the University of Missouri Medical School, St. Louis University School of Medicine, the University of Minnesota Medical School, Wisconsin University, and Northwestern University Medical School.

I would like now to describe several of our recent successes.

X-Ray Enhancement

In connection with a study of equipment and techniques for processing and diagnosing x-rays, medical investigators at the University of Missouri Medical School asked us to assist them in the problem of enhancing the contrast in x-ray films. A search of the NASA literature revealed a technique for enhancing x-ray photographs, developed at the Jet Propulsion Laboratory, which was derived from techniques developed

Presented at the Annual Meeting of the Association for the Advancement of Medical Instrumentation, Houston, Texas, July 17, 1968.

in the Mariner space program.^{1/} In brief, the basic technique is to first convert the original photograph into digital form, then a computer program is applied to enhance the data, and finally the enhanced data is converted back into a photograph (Figure 1). The x-ray on the left is an original angiogram of a human skull, taken to show the blood vessels in the head. The photograph on the right is the same x-ray after it had been processed by the JPL system. Note how much clearer the blood vessels stand out in the enhanced photograph.

The University of Missouri Medical School is now considering setting up an x-ray enhancement system based on the JPL system. Consideration is also being given to setting up such a system at the University of Kansas Medical Center. In the later institution, the data will be transmitted from the hospital in Kansas City to the computer located at Lawrence, about 30 miles away, processed and transmitted back to the hospital in a matter of a few minutes.

Ear Specimens

The internal ear, called the labyrinth (because of its complicated structure) consists of two parts, a series of cavities within the temporal bone, and the membranous labyrinth, which is a series of communicating sacks and ducts contained within the bony cavities. The inner ear of a cat with the surrounding bone is shown in Figure 2. In the preparation of specimens of the membranous labyrinth, it is necessary to remove the

outer bone without injuring the delicate internal structure. This is normally a tedious, time-consuming task of dissolving and chipping away the bony structure. The MRI BA Team suggested using a special air abrasive device. Dr. Fernando Kirchner, University of Kansas Medical Center, tried this device and found that it worked very well.^{2/} Figure 3 shows the operation. A majority of the bone is removed with the air-abrasive device in a comparatively short period of time. The remainder of the bone is removed with a decalcifying agent. Accurate specimens of the inner ear have been successfully obtained in this manner. Figure 4 is a specimen of a cat's inner ear, and Figure 5 is a human inner ear, both obtained with this new technique, by Dr. Kirchner at the University of Kansas Medical Center.

Temperature Telemetry

At the University of Wisconsin, a long-range study of the reproductive process is being conducted. In connection with this work, there is a need to measure the temperature of the internal organs in monkeys. Temperature changes as small as $2/100^{\circ}\text{F}$ must be detected, and the instrument must remain operative inside the animal over a period of several months.

A search of the NASA literature revealed work done at the NASA Ames Research Center, California, on a tiny temperature telemetry unit,^{3/} shown in Figure 6. Information on this unit was forwarded to the

investigators at the University of Wisconsin. Two of these units were obtained through a commercial source, and are now being tested inside monkeys. The last report indicated that the units are working very satisfactorily after being implanted for over three months.

Remote Examination of Patients

As a part of the health system in the proposed university of Minnesota Experimental City Project, consideration is being given to a system which will permit a patient to be examined in the home by a physician at a remote location, such as a neighborhood health center. The idea is that such a system would encourage citizens to cooperate with the health care program on a preventative "stitch in time saves nine" basis. A search of the literature revealed a system for monitoring patients remotely, which has been developed by the Boeing Company for the NASA Marshall Space Flight Center.^{4/} The system consists of a central control station and a number of battery-operated patient units, consisting of small strap-on electronic packages, shown in Figure 7. The patient units are designed to ensure minimum encumbrance and discomfort to the patients. A complete unit, including batteries, weighs less than 1 lb. The system, which has now undergone feasibility tests, is capable of collecting 6 channels of data, including electrocardiograms, temperatures, blood pressure, etc., from up to 64 patients.

Other recent transfers, which have been completed or in progress, include:

1. Non-intrusive method to measure cardiac output.
2. Respiratory gas analyses, on a breath-to-breath time basis.
3. Sterile operating and post-operative rooms.
4. Measurement of bone distortion and integrity.
5. Micro-circulation measurement.
6. A flexible/rigid tether for prosthetics.
7. An improved system for delivering medication to the respiratory tract.

In summary, the MRI Biomedical Applications Team is very active in applying aerospace technology to bioengineering problems. Although the program has been in operation for a comparatively short period of time, there have already been a considerable number of successes and more are on the way.

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LIST OF FIGURES

- Fig. 1 - Left: Angiogram of Skull Prior to Processing
Right: Same Angiogram After Processing (Ref. 1)
- Fig. 2 - Inner Ear of Cat with Surrounding Bone (Courtesy Dr. F. Kirchner, University of Kansas Medical Center)
- Fig. 3 - Inner Ear Bone Being Removed with Air Abrasive Device (Ref. 2)
- Fig. 4 - Inner Ear Specimen of Cat After Bone Removal (Courtesy Dr. F. Kirchner, University of Kansas Medical Center)
- Fig. 5 - Human Inner Ear Specimen (Courtesy Dr. F. Kirchner, University of Kansas Medical Center)
- Fig. 6 - Temperature Telemetry System (Ref. 3)
- Fig. 7 - Strap-on Biotelemetry Wrist Unit (Ref. 4)

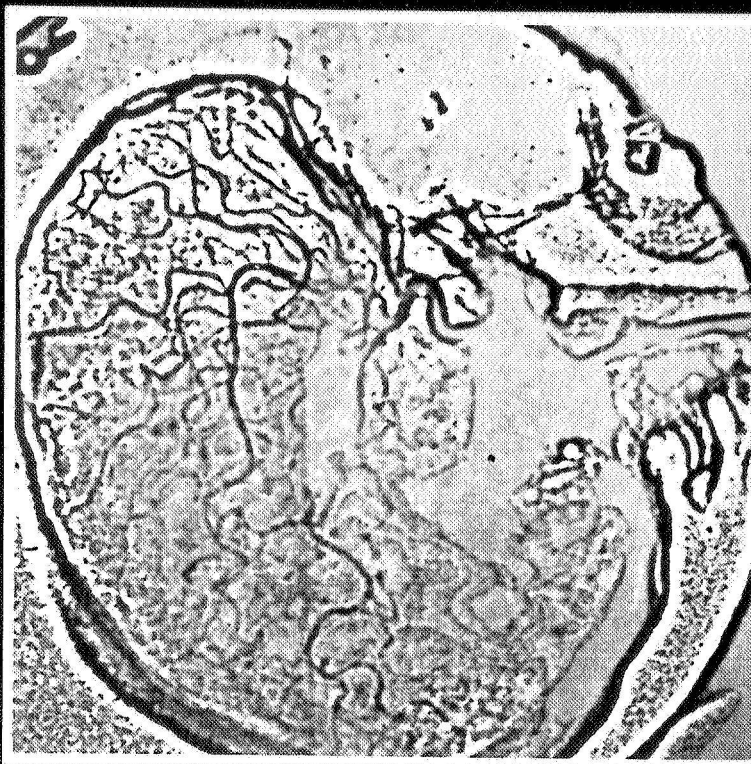


Fig. 1 - Left: Angiogram of Skull Prior to Processing
Right: Same Angiogram After Processing
(Ref. 1)



Fig. 2 - Inner Ear of Cat with Surrounding Bone (Courtesy Dr. F. Kirchner, University of Kansas Medical Center)

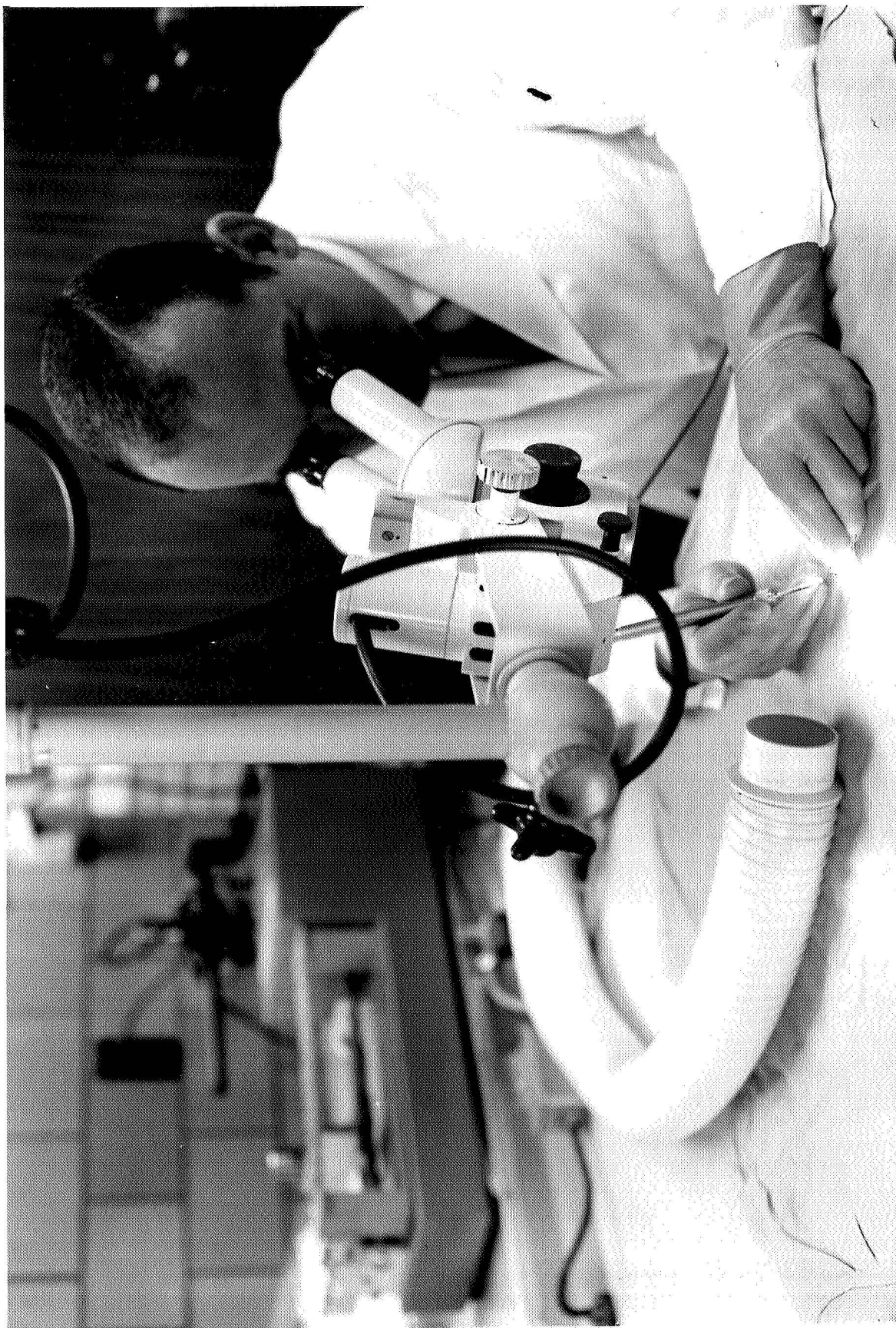


Fig. 3 - Inner Ear Bone Being Removed with Air Abrasive Device (Ref. 2)



Fig. 4 - Inner Ear Specimen of Cat After Bone Removal (Courtesy Dr. F. Kirchner, University of Kansas Medical Center)

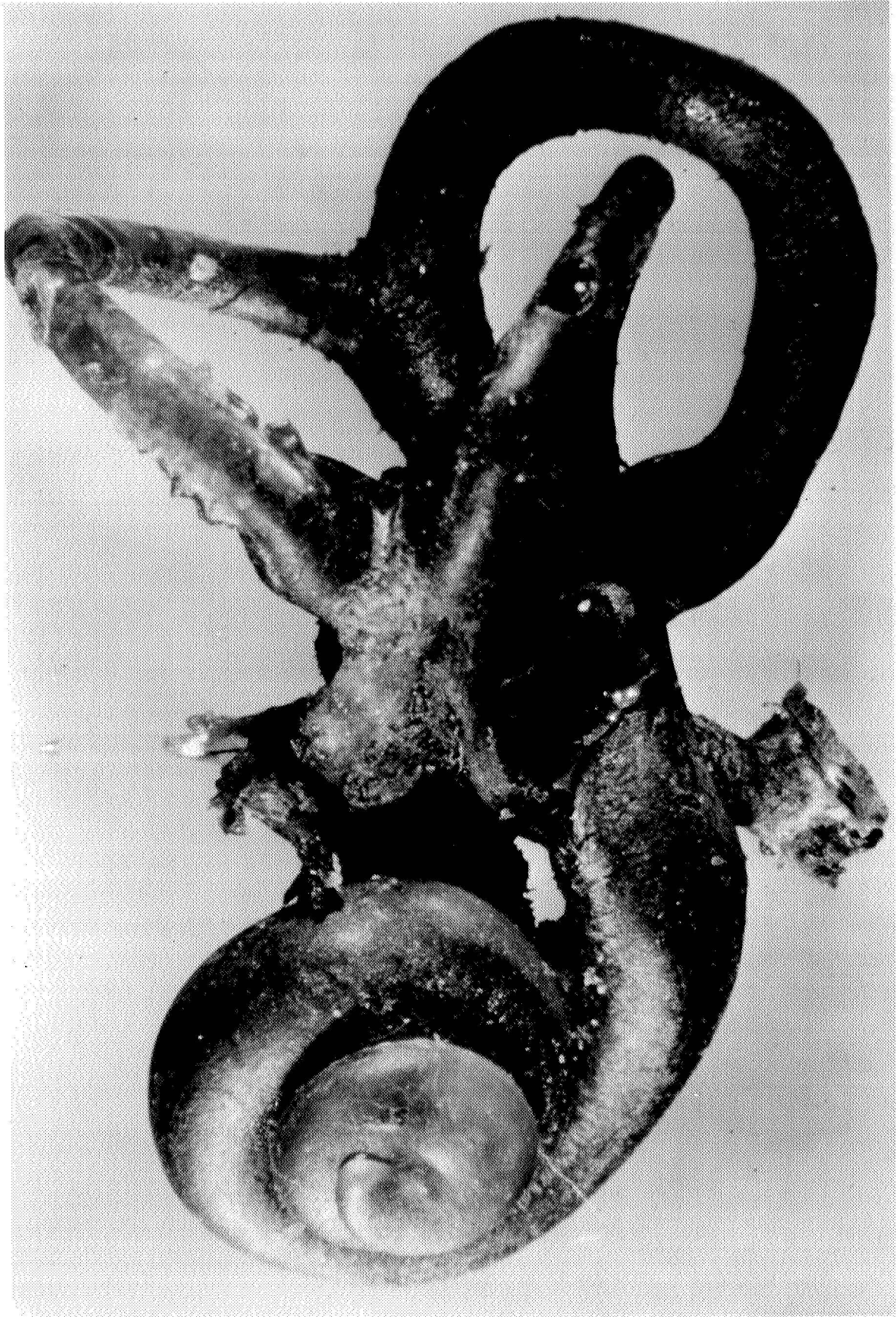


Fig. 5 - Human Inner Ear Specimen (Courtesy Dr. F. F. Kirchner, University of Kansas Medical Center)

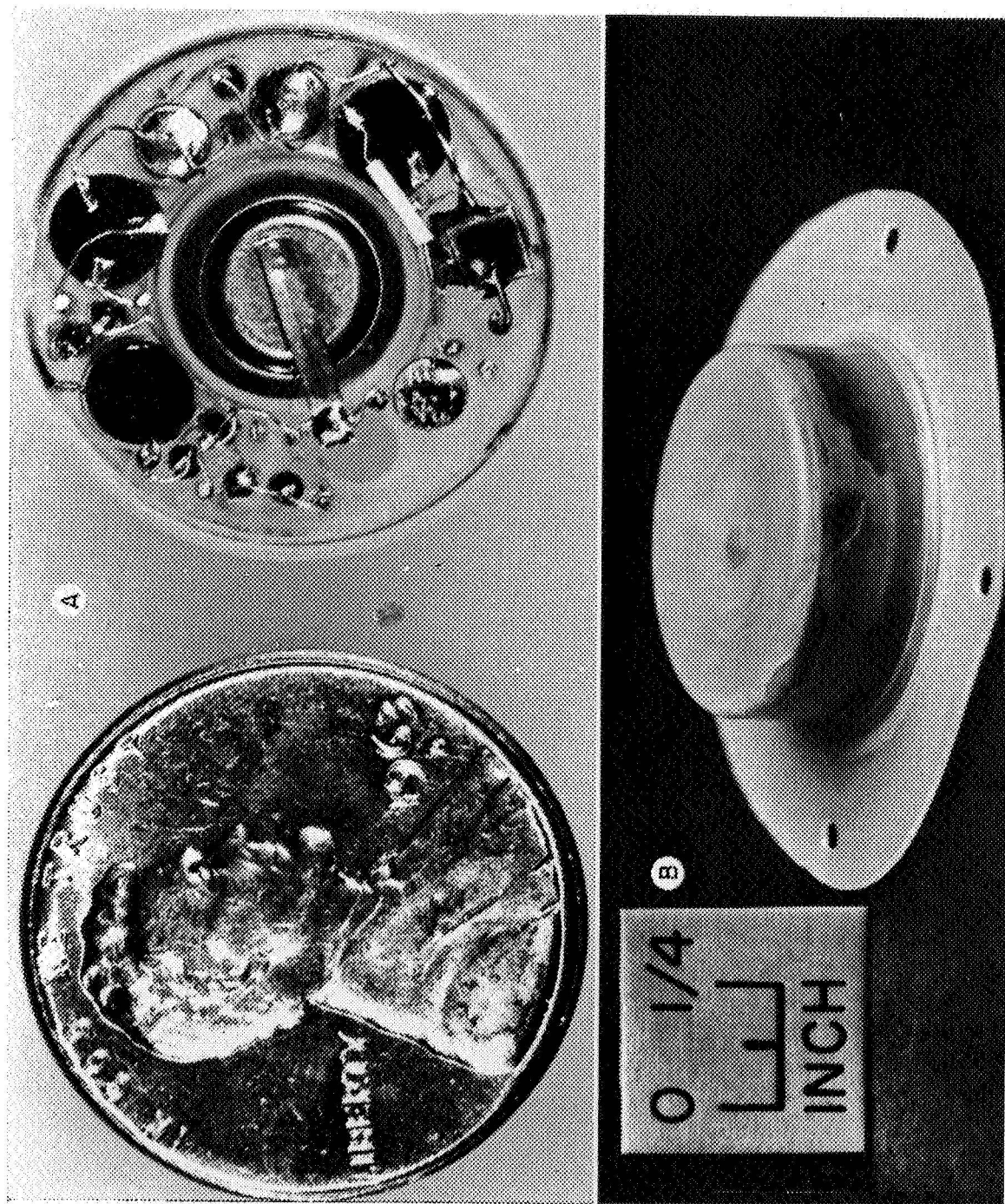


Fig. 6 - Temperature Telemetry System (Ref. 3)

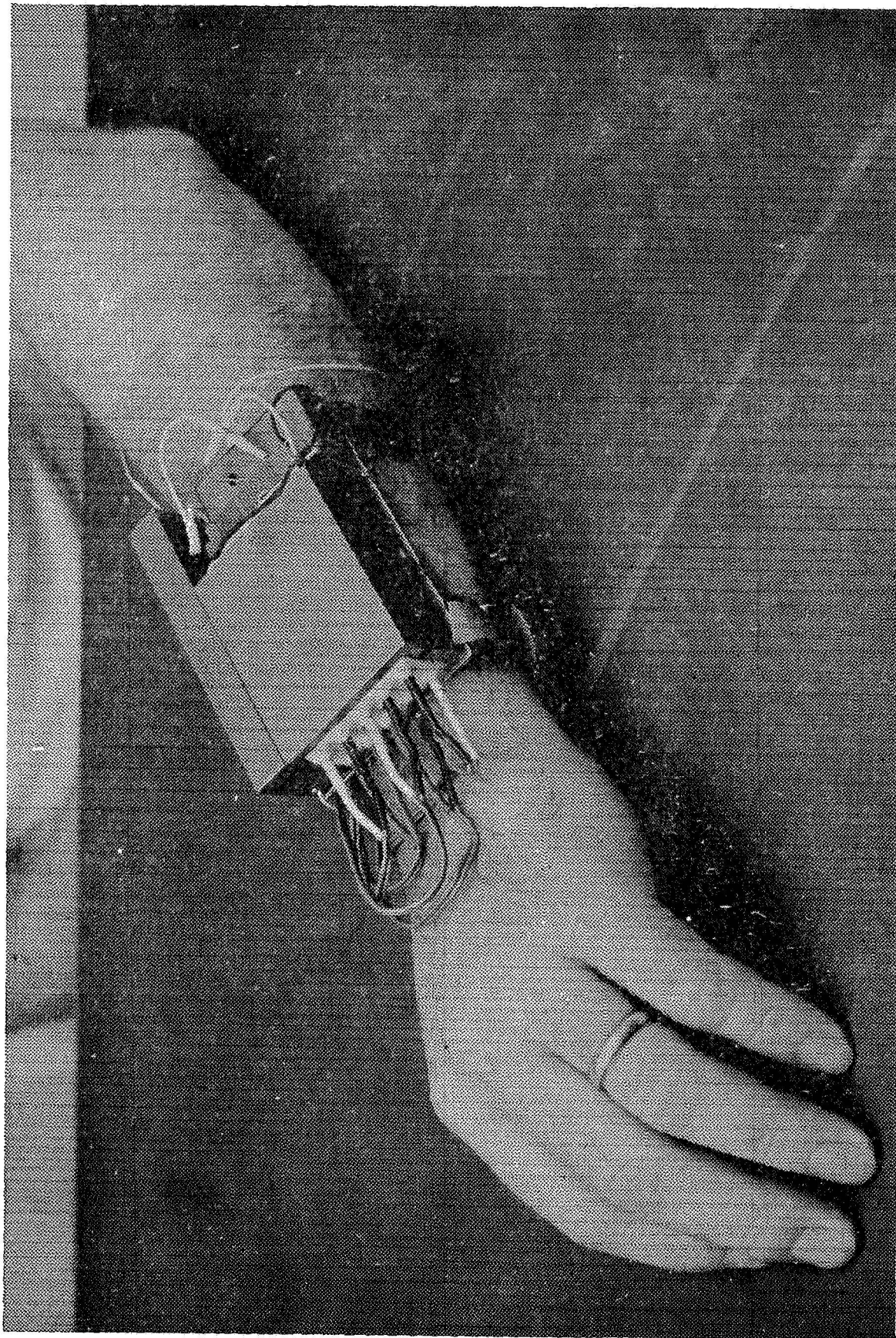


Fig. 7 - Strap-on Biotelemetry Wrist Unit (Ref. 4)

EVALUATING AEROSPACE TECHNOLOGY IN THE MEDICAL SETTING

by

David Bendersky
Director, MRI Biomedical Applications Team

One of the most important and critical steps in the process of transferring aerospace technology to the medical field is the evaluation of the technology in the medical setting. This is where potential solutions are proven or disproven. The success or failure of the evaluation is dependent on a number of factors, including the quality of the particular technology being considered, good communications between all parties involved, a thorough understanding of the capabilities and limitations of the technology, the procurement of appropriate hardware, the adaptation and modification of the original technology to the medical application, and adequate time, funds and personnel to properly evaluate the technology.

When an aerospace literature search or other information retrieval procedures revealed a potential solution to a medical equipment problem, all possible information about the technology is obtained by the Biomedical Applications Team. All available published and unpublished reports on the technology are obtained from the NASA research center or the NASA contractor who was responsible for developing the technique. If the

Presented at the Annual Meeting of the Association for the Advancement of Instrumentation, Houston, Texas, July 17, 1968.

reports appear promising, they are furnished to the medical investigator for his consideration. When appropriate, the medical investigator and the Biomedical Applications Team members visit the NASA installation or NASA contractor for personal discussions with the people who developed the technology.

If the evaluation of the information appears promising, the next step is usually the procurement of "hardware" for tests. In some cases a test model can be furnished by NASA. The Biomedical Applications Team will assist the medical investigator in procuring items from NASA, when such items are available. When hardware is not available through NASA, the medical investigator must make other arrangements to procure the hardware. Low cost items may be purchased directly from the investigator's resources. In the case of expensive equipment, funds are usually applied for through a grant.

In many cases, some modification of the original aerospace technology is required to adapt it to the specific medical application. If the medical investigator requires engineering assistance, each of the BA Teams represent organizations which are in a position to provide such services.

The medical investigator is entirely responsible for evaluating the aerospace technology for his particular application. He must determine the conditions under which the technology is to be tested and must make all arrangements for the tests. Furthermore, he is responsible for analyzing and interpreting the results of the tests. The BA Team will

assist the medical investigator during the evaluation tests, on a consulting basis, when requested.

At the conclusion of the evaluation tests, the medical investigator is obliged to report the results to the BA Team. If the results are positive, the medical investigator is encouraged to prepare a paper for publication in an appropriate medical journal so that the technique can be considered by others in the medical field.

Several items of NASA technology which have been successfully evaluated for non-space medical applications under the NASA Biomedical Applications Program, are shown in the Figures 1-3. The three items are (1) a respirometer helmet which was developed to replace the conventional rubber mouthpiece, (2) a muscle accelerometer which is being used to measure muscle reflexes and tremors, and (3) spray-on electrodes for electrocardiograms.

I am pleased to be able to report that each of these NASA originated items is now being routinely used in non-space medical applications. The respirometer helmet has been used to collect respiratory data on over 400 children at the University of Kansas Medical Center alone, and is now being used in several other medical institutions. The muscle accelerometer is being used not only to measure muscle reflexes but is being used to measure tremors in a study of neurological problems at the St. Louis University. At Washington University Medical School, the instrument is being used to measure larynx movement. And, the spray-on electrodes have proven themselves on thousands of subjects and is now available commercially.

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LIST OF FIGURES

Fig. 1 - Respirometer Helmet Used to Measure Oxygen Consumption

Fig. 2 - Muscle Accelerometers Used to Measure Arm and Hand Motions

Fig. 3 - NASA Spray-On Electrocardiogram Electrodes Being Applied



Fig. 1 - Respirometer Helmet Used to Measure Oxygen Consumption

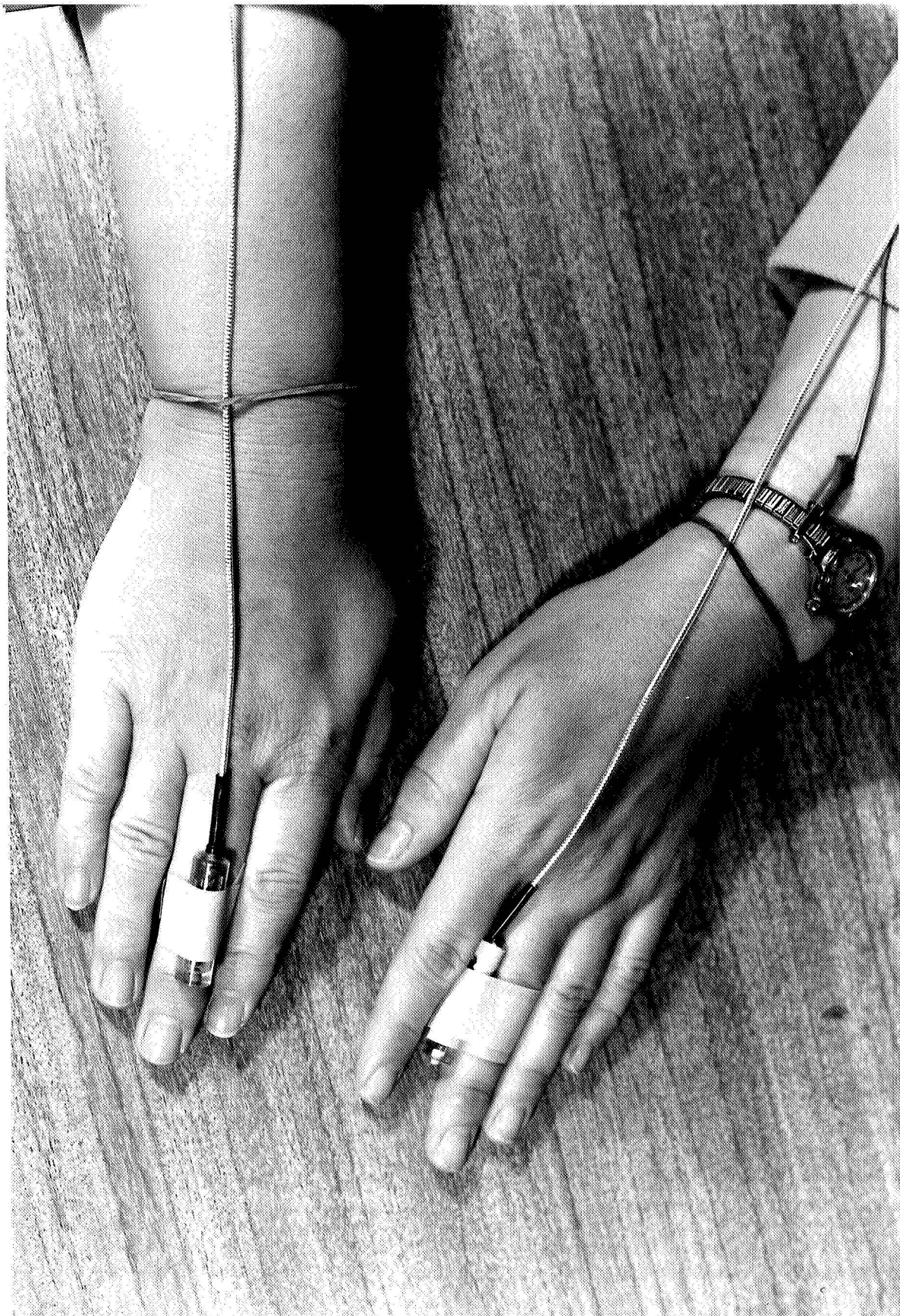


Fig. 2 - Muscle Accelerometers Used to Measure Arm and Hand Motions

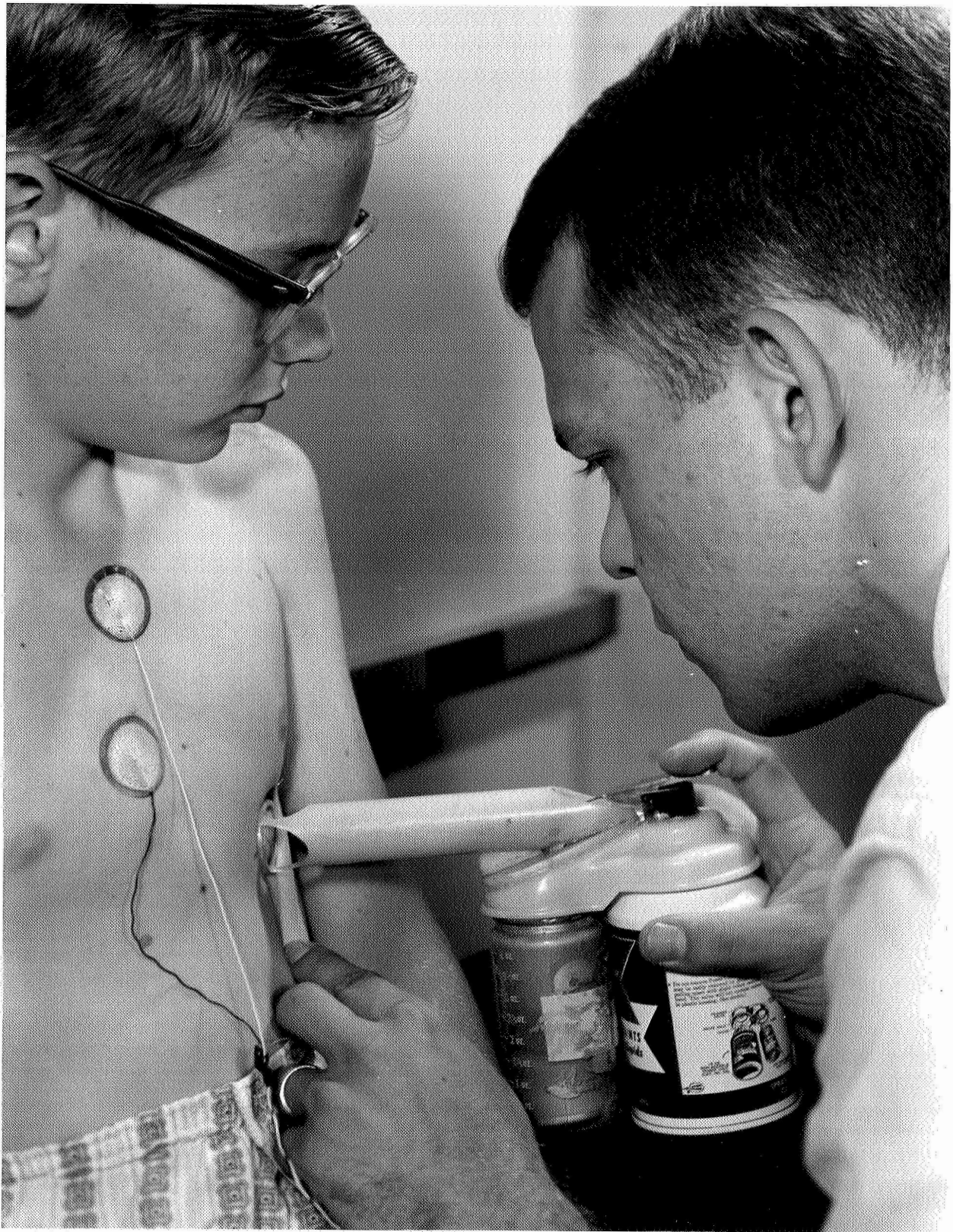


Fig. 3 - NASA Spray-On Electrocardiogram Electrodes Being Applied

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